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PATENT

INVENTORS: Cheng A. FENG
Jason D. HIBBELER
Theodore G. HOOVER Jr.
Judith K. INGLES
Jhy-Chun WANG

AUTOMATED CONFIGURATION OF ON-CIRCUIT FACILITIES

Background of the Invention

1. Field of the Invention

This invention generally relates to the field of automated circuit configuration tools, and more particularly relates to the use of an automated method and system to configure profiles for circuit monitoring hardware and to ensure that the configured profile satisfies the limitations of the circuit monitoring hardware.

2. Description of Related Art

Complex electronic circuits, especially digital processing circuits, sometimes incorporate modules that are able to monitor events that occur within the circuit. These circuits often allow configuration of some or all of these event monitors to monitor one of a number of events that occur within the circuit. Complex microprocessor circuits are an example of circuits which incorporate a number of such event monitors. Examples of such monitors include counters which count intra-circuit events. Examples of events that are monitored in a complex microprocessor include cache memory misses, floating point operations, fixed point math operations, program branching and events associated with processing pipeline operations. Incorporating event monitors into these circuits provides an efficient method of monitoring the performance of the circuit under a variety of conditions.

Complex processing circuits often have a large number of events which may be monitored. These processing circuits often incorporate fewer monitors than there are events to be monitored but allow configuration of the monitors to allow selection of the events which are to be monitored. This architecture requires a selection of the subset of available events to monitor. The complex processing circuit may also limit the electrical connection of some events to only a subset of monitors. This results in further restrictions on the monitor configurations that can be chosen. In selecting events to be monitored, a designer must manually remember which events can be monitored by each monitor and limit his or her selections accordingly.

In order to define which events in a circuit are to be monitored, the designer must match each monitor to one of the events occurring within the circuit. This requires circuit designer to manually define which event is to be monitored by which monitor. When determining these event-monitor pairs, the designer must also manually remember which events have already been configured to be monitored so that multiple monitors are not wasted by monitoring the same event. This process becomes significantly difficult as the number of monitors and events increases within a circuit.

The manual configuration of the event-monitor pairs for a complex circuit is therefore tedious and requires a skilled designer to spend time to ensure that a specified configuration will work. Therefore a need exists for a simplified technique to specify event-monitor associations in circuits incorporating monitors of intra-circuit events.

Summary of the Invention

According to a preferred embodiment of the present invention, the automated configuration of on-circuit monitoring facilities provides a method of compiling an on-

circuit monitor profile to be used to characterize the performance of a processing circuit which consists of storing a set of allowable associations of a plurality of monitors and a plurality of events, presenting the set of allowable associations to a user, allowing the user to specify a selected set of monitor and event associations, wherein the selected set of monitor and event associations is a subset of the set of allowable associations, and preparing a monitor profile, wherein the monitor profile is to be used to configure on-circuit monitors.

The present invention, according to a preferred embodiment, comprises a system for compiling an on-circuit monitor profile used to characterize the performance of a processing circuit that has a monitor configuration file for storing a set of allowable associations of a plurality of monitors and a plurality of events, a display to display the set of allowable associations to a user, a user input for allowing the user to specify a selected set of monitor and event associations, wherein the selected set of monitor and event associations is a subset of the set of allowable associations, and a monitor profile output, electrically connected to the user input, wherein the monitor profile output is to be used to configure on-circuit monitors.

Brief Description of the Drawings

FIG. 1 is a block diagram illustrating a complex circuit that incorporates monitoring facilities.

FIG. 2 is a block diagram illustrating a complex circuit that incorporates monitoring facilities and that is able to be configured by a preferred embodiment of the present invention.

FIG. 3 is a block diagram illustrating a complex circuit that includes on-circuit monitoring facilities and an automated configuration apparatus according to a preferred embodiment of the present invention.

FIG. 4 is an exemplary Graphical User Interface (GUI) display for use with a preferred embodiment of the present invention.

FIG. 5 is an alternative Graphical User Interface (GUI) display for use with a preferred embodiment of the present invention.

Description Of The Preferred Embodiments

The present invention, according to the illustrated embodiments, overcomes problems with the prior art by providing users with a pre-configured, easy-to-grasp representation of valid event-monitor associations and allowing the user to select desired associations from this presentation of valid associations. The present invention, as shown by the illustrated preferred embodiments, also stores the selected associations of event-monitor associations for later use or recall for modification.

An example circuit 100 which will utilize the benefits of the present invention is shown in FIG. 1. Circuit 100 comprises the operating hardware 102 and an on-circuit group of monitors 104. The on-circuit group of monitors 104 in the illustrated preferred embodiment contains a plurality of monitors, e.g. monitor N 110 and monitor M 112. The operating hardware 100 has a number of events, e.g. event A 120 and event B 122, which may be monitored by one of the monitors contained in the group of monitors 104.

The example circuit 100 is shown to be configured so that each monitor has been connected to an associated intra-circuit event. The monitors of the illustrated

example circuit 100 are event counters and each event counter accepts one input. Alternative embodiments may utilize monitors with multiple inputs. The connection between each of the counters in the group of monitors 104 and the event outputs of the operating hardware are shown by the connections 114. Connections 114 may be implemented in various embodiments by electrical switching which connects the event outputs to the associated monitor. Other connection techniques are known to practitioners in the relevant arts. The connections 114 are controlled in the illustrated embodiment by software through the monitor Application Program Interface (API) software component 202.

FIG. 2 illustrates an example processor architecture 200 which is configured through the use of a preferred embodiment of the present invention. The example processor architecture 200 is a microprocessor that includes software execution hardware as the operating hardware 102 and a group of monitors 104 that contains, in this example, four counters, including exemplary counter N 110 and counter M 112. The example processor architecture 200 is similar to a Power PC 604e Microprocessor. The example processor architecture 200 further contains a monitor API software component 202. The monitor API software component 202 configures the processor hardware so as to associate selected events with counters in the group of monitors 104 of the illustrated embodiment. The monitor API software component 202 of the illustrated embodiment configures routing switches within the microprocessor to select and route the event indicators 208 that are associated with selected events to the proper counter within the group of monitors 104. The monitor API software component 202 also is able to read the value of the counters within the group of monitors 104 and provide the counter values to a profiling tool 204. The profiling tool 204 communicates to an external process through an external interface 206. The profiling tool 204 relays the counter values through the external interface 206 for analysis. Profiling tool 204 may store counter values during processing by the operating hardware and then provide those stored values through the external interface 206 after the processing is

performed by the operating hardware 102. The profiling tool 204, according to a preferred embodiment, is embedded code resident in a memory of the microprocessor architecture. However, other alternative arrangements for providing the profiling tool 204 in a system should be obvious to those having ordinary skill in the art in view of the present discussion. For example, the profiling tool 204 may comprise a computing circuit external to the microprocessor architecture that is communicatively coupled to the monitor API 202 that is preferably embedded in the microprocessor architecture.

The profiling tool 204 also accepts monitor configuration data through external interface 206. The configuration data is provided to the monitor API software component 202 to command the proper configuration of the monitoring hardware so that the selected events 206 are associated with the specified counters in the group of monitors 104. External interface 206 in the illustrated embodiment utilizes an intermediate file, counter group configuration file 306, as the communications mechanism. External interface 206 in other embodiments of the present invention may be an inter-process communications mechanism to another processing thread that is executing within the same processor as the operating hardware 102. Alternative embodiments may also utilize a communications path external to the processor for analysis on another processor.

FIG. 3 illustrates an example configuration apparatus 300 according to a preferred embodiment of the present invention. Example configuration apparatus 300 includes an example processor architecture 200 that is connected to a Graphical User Interface (GUI) software component 304. Example embodiments may execute the GUI software component on the same computer as the example processor architecture 200, or a separate processor may be utilized by alternative embodiments. The GUI 304 according to a preferred embodiment of the present invention is used to present to a user the associations that may be made between events in the operating hardware102 and monitors within the group of monitors 104. The available associations between

events and monitors may be limited by the processor hardware such that some events may only be monitored by a subset of the monitors in the group of monitors 104.

The allowable combination of events and monitors in the illustrated embodiment is stored in the monitor event configuration file 302. The monitor event configuration file 302 contains data dependent upon the example processor architecture 200. The monitor event configuration file 302, according to the present example, is communicatively coupled (via a data interface 310) with the GUI 304. The data stored in the monitor event configuration file 302 is used by the GUI 304 to present and verify allowable associations of events and monitors to users of the illustrated preferred embodiment of the present invention.

The GUI 304 according to the illustrated preferred embodiment is used to present to a designer a graphical representation of the possible associations of events and counters which may be selected. An example GUI display 400 presented by the illustrated preferred embodiment is shown in FIG. 4 and is discussed below. The GUI 304 reads a list of allowable event to counter assignments from the Monitor Event Configuration File 302. The output of the GUI 304 is an on-circuit monitor profile. The on-circuit monitor profile is used to configure the example processor architecture 200, and especially the monitor API software component 202. The on-circuit monitor profile in the illustrated embodiment is also stored in the monitor group configuration file 306 for future recall into the GUI 304 through file to GUI link 312 for reuse or modification. The on-circuit monitor profile may also be directly read by the profiling tool 204 of the illustrated embodiment directly or the on-circuit monitor profile may be read by analysis software in association with monitor data collected by the profiling tool 204 in order to determine the configuration of the monitoring hardware in the example processor architecture 200 when analyzing the counter data.

FIG. 4 illustrates an example presentation 400 in a GUI 304 of the contents of a sample monitor event configuration file 302. GUI 304 receives the monitor event configuration from the monitor event configuration file 302 and displays the data in an easily readable format.

Example presentation 400 shows one row for each event which may be monitored, which are identified as event 1, 2, 3 and so on, and one column for each counter, identified as counter 1, 2, 3 through 8. A box at the intersection of each row and column allows a user to select an association between the event and counter common to that box. The user may use the facilities of the GUI interface 302 to select a box, and the GUI interface will record that selection. The selection is indicated in the example presentation 400 as a check mark in the box. Example presentation 400 shows selections associating event 1 with counter 1, event 2 with counter 3, event 3 with counter 2 and so on. The selected associations are then stored into the on-circuit monitor profile. The processing associated with example presentation 400 may verify that selected associations are valid, as defined within a monitor event configuration file 302, and notify the user if a selected association is invalid.

FIG. 5 illustrates an alternative presentation 500 that indicates that some monitors may not be associated with some events. The absence of a mark at a column-row intersection indicates that the counter cannot monitor that event. Alternative presentation 500 does not include boxes at the intersection of some rows and columns. The absence of these boxes reflects that the association represented by that row and column is not allowable. Alternative presentation 500 shows an absence of selection boxes for the associations of counter 5 to events 1 and 2 as well as for the association of counter 8 to events 3 and 4. These associations are not allowed in the example processor architecture 200 due to its design. The data which contains the allowable associations is stored in the monitor event configuration file 302.

The present invention allows significantly greater productivity and ease of flexibility in configuring on-circuit testing facilities by allowing software developers to easily configure on-circuit test facilities and to store and recall the configurations that have been set up by the developer. The present invention allows a user to recall stored configurations for re-use or modification into new test configurations. The ability to easily and quickly reconfigure the on-circuit test facilities reduces the development time required to optimize software and encourages software developers to optimize their software. The present invention also easily allows and encourages the user to evaluate alternative system configurations and/or processing architectures. The more fully optimized software which is economically developed with the present invention results in faster and more efficient computer and supercomputer utilization. The present invention also allows the pre-definition of a variety of on-circuit test facility configurations that can be easily used by less experienced software developers to gather data associated with phenomena of interest. The easy recall and modification of these pre-defined configurations encourages the use of on-circuit test facilities and also encourages the use of various configurations of the on-circuit test facilities to better characterize the operations of interest.

The present invention can be realized in hardware, software, or a combination of hardware and software. A system according to a preferred embodiment of the present invention can be realized in a centralized fashion in one computer system, or in a distributed fashion where different elements are spread across several interconnected computer systems. Any kind of computer system - or other apparatus adapted for carrying out the methods described herein - is suited. A typical combination of hardware and software could be a general purpose computer system with a computer program that, when being loaded and executed, controls the computer system such that it carries out the methods described herein.

The present invention can also be embedded in a computer program product, which comprises all the features enabling the implementation of the methods described herein, and which - when loaded in a computer system - is able to carry out these methods. Computer program means or computer program in the present context mean any expression, in any language, code or notation, of a set of instructions intended to cause a system having an information processing capability to perform a particular function either directly or after either or both of the following a) conversion to another language, code or, notation; and b) reproduction in a different material form.

Each computer system may include, inter alia, one or more computers and at least a computer readable medium allowing a computer to read data, instructions, messages or message packets, and other computer readable information from the computer readable medium. The computer readable medium may include non-volatile memory, such as ROM, Flash memory, Disk drive memory, CD-ROM, and other permanent storage. Additionally, a computer medium may include, for example, volatile storage such as RAM, buffers, cache memory, and network circuits. Furthermore, the computer readable medium may comprise computer readable information in a transitory state medium such as a network link and/or a network interface, including a wired network or a wireless network, that allow a computer to read such computer readable information.

Although specific embodiments of the invention have been disclosed, those having ordinary skill in the art will understand that changes can be made to the specific embodiments without departing from the spirit and scope of the invention. The scope of the invention is not to be restricted, therefore, to the specific embodiments, and it is intended that the appended claims cover any and all such applications, modifications, and embodiments within the scope of the present invention.

What is claimed is: